SunShot Grand Challenge Breakout Session

DISRUPTIVE SOLAR TECHNOLOGIES

Frontiers in New Materials and Approaches

Wednesday, May 21, 2014, *10:45 – 11:45 AM* Anaheim, California

Disruptive solar technologies entering the PV and CSP landscape today hold the potential to greatly impact the future of solar energy conversion. This session will highlight new techniques, processes, materials, and 'game changing' revelations over the last several years, while also exploring the major obstacles to commercialization. Three speakers will provide fifteen minute presentations on promising areas including perovskites for photovoltaics, inverse design, and photon enhanced thermionics.

Prof. Alex Zunger
University of Colorado Boulder

The usual-suspects PV materials, resurrected materials, and the quest for new, designed materials

Abstract: Looking at the famous Kazmerski plot of cell efficiency vs year for different PV materials as well as at the research activities currently funded one can make the following simple observations:

(i) The *"usual suspects" materials* (Si, CdTe, CIGS) have progressed slowly but surely at an enormous cumulative cost over >35 years of investment.

(ii) *Resurrected (earth abundant) materials:* Materials discovered over 100 years ago and selected in the last ~10 years for studying their PV activity (Cu_2O, FeS_2, SnS, SbS, CZTS, to name a few) are now referred to as "new materials." Yet, in the absence of sufficient fundamental materials science studies, the reasons for their individual failure modes (Fermi level pinning in CZTS; metallic surface precipitates in FeS_2) are slow to be recognized, leading to periodically repeated studies of the same stuff.

At the same time, standard compilations of all previously made inorganic compounds cover as many as 200,000 entries, but their PV-relevant properties are mostly unknown. Could it be that some winning *future PV materials* hide in this database? How are we going to go about pre-screening these, narrowing them down to, say, 10 best candidates?

In this talk I will discuss a possible strategy that has been used in other areas of materials science: *The Inverse Design approach*. The idea is to put the target-desired functionality first, and seek deliberately materials that satisfy it. One could filter theoretically (using Quantum Mechanics) materials that satisfy some basic metric (analogous to, but much more compelling than the Schockley-Quiesser metric) .The best candidates are then subjected to experimental scrutiny, iterating the discoveries with theory. Initial steps in this grand-vision and obstacles encountered will be pointed out.

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Prof. Jonathan E Spanier

Drexel University

Game-Changing Perovskite-Based Photovoltaics

Abstract: Semiconducting perovskites attract considerable attention for their potential application in novel low-cost and efficient photovoltaics. Two distinct classes of materials having the perovskite structure in common have emerged as promising new solar absorbers.

Efficiencies of hybrid organometallic-inorganic perovskite cells have quickly eclipsed dye-sensitized solar cells. Heralded for the much lower growth temperatures at which essentially defect-free crystalline films can be formed as compared with traditional semiconductors and for the much higher diffusion lengths compared with other organic electronic materials, remarkable progress has been made in efforts to achieve long-term operational stability and in producing larger-area films, even as use and management of lead could be viewed as a concern.

Ferroelectric oxide perovskites have strong inversion symmetry breaking due to spontaneous polarization, allowing excited carrier separation throughout the bulk of the material and open-circuit voltages higher than the band gap. While polar oxides are highly stable and can be composed of inexpensive, earth-abundant elements, the inherently large band gaps of robust ferroelectric oxides allow use of only 8-20% of the solar spectrum and drastically reduce the upper limit of efficiency. The synthesis of a robust system where the ferroelectric response is combined with a band gap in the visible range has been elusive until recently.

Key barriers must be overcome before perovskite-based PVs can become practical technology. The state-of-the-art in materials design, synthesis and processing, and property and device characterizations of both hybrid organometallic-inorganic and polar oxide perovskites will be highlighted, and selected challenges discussed.

Prof. Nick Melosh

Stanford University

Nx-TEC: Next-Generation Thermionic Solar Energy Conversion

Abstract: Topping cycles that could provide additional efficiency for Concentrated Solar Power (CSP) are a promising means to lower the cost per watt. However, these systems require operating temperatures in the 400-700 °C range, severely limiting possible technologies. For high temperature conversion thermionic emission has long been an attractive idea for its potential high-efficiency with no moving parts and simple device geometry. However, previous generations of convertors have had relatively poor actual performance due to space charge effects, high temperatures (>1500 °C) and low output voltages, which restricted their practical implementation. The Nx-TEC program is using a combination of modern microfabrication techniques and a new idea that combines both photovoltaic and thermionic effects together to create highly efficient conversion devices. We demonstrate initial results based upon photon-enhanced thermionic emission (PETE) that is effective in the desired temperature range may lead to higher overall efficiency. We will discuss challenges and approaches for CSP thermal cycles based on electron emission, and the outlook for future device implementation.